BROWN, VENCE & ASSOCIATES

Appendix A
Numerical Modeling

BVA

Appendix A

NUMERICAL MODELING

Simplified analytical modeling was performed to assess the relative influence of geologic conditions on the performance of various liners with respect to preventing groundwater contamination. The purpose of the modeling was comparative rather than predictive and a variety of analytical fate and transport models were evaluated for use on this project. Both wastewater retention ponds and corrals were modeled because previous studies (e.g., BVA 2003; Ham 2002; Adriano et al. 1971; Maule' and Fonstad 2000) have demonstrated that these areas of confined animal facilities represent potential threats to groundwater quality. No specific information regarding potential groundwater contamination from milk parlors has been identified to date (BVA 2003); as a result, modeling was not performed for these areas.

Models Used for Analysis

The transient model SEVIEW (v 6.2.6) and the steady-state model MULTIMED (v 2.0) were selected for use on this project. Both MULTIMED and SEVIEW solve a linear advection-dispersion equation, which means that if all other parameters are held constant, the model-predicted concentrations in groundwater are linear functions of the input concentrations (MULTIMED) or loading rates (SEVIEW). Therefore, the model outputs can be used to develop a ratio of input to groundwater concentrations that will remain constant for any input value, all other factors remaining equal.

Retention pond leakage represents a nearly steady-state condition because leakage occurs continuously whenever liquid is present. It was therefore assumed that liquid would be present throughout the year, although levels in the retention pond may rise and fall seasonally. The computer program MULTIMED was used to evaluate one-dimensional steady-state analysis of flow in the unsaturated zone and groundwater. MULTIMED was developed by the EPA to simulate the transport and transformation of contaminants released from a waste disposal facility into the air or soil. Like SESOIL, it is a screening-level tool that can be run with less detailed input parameters than other models, and is therefore well-suited for comparative analyses. It should be noted, however, that a steady-state analysis is not time-dependent and provides no information regarding the length of time required to affect groundwater. The results simply provide an indication of whether or not groundwater will ultimately be affected at some level.

The transient computer program SEVIEW was used to evaluate waste migration from the ground surface to the groundwater from corral areas at confined animal facilities. A transient model was preferred for corral areas because precipitation in the Central Valley is strongly seasonal and storms are irregularly distributed during the wet season. As a result, waste constituents are likely to accumulate in shallow soils during dry periods and to leach soluble constituents during storm events. SEVIEW incorporates the unsaturated zone fate and transport model SESOIL and the generalized three-dimensional groundwater model AT123D so that the transport of contaminants can be modeled from the ground surface,
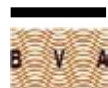
through the unsaturated zone, into and through an aquifer.[1] The principal advantage of SEVIEW for this project is that it is a screening-level model that requires less soil, chemical, and climatological input data than most other similar models. In general, SEVIEW requires a contaminant input loading rate and then calculates a resulting concentration in groundwater based on precipitation data and user-defined subsurface conditions. Because SEVIEW is a transient model, it also provides information on breakthrough time (i.e., the time required for a contaminant to impact the groundwater) as a function of subsurface and contaminant properties.

Model Input Parameters

Assumed Geologic Conditions

Modeling was performed to compare the relative vulnerability of different thicknesses and material types in the unsaturated zone. The purpose of this effort was to evaluate the effect, if any, of differences in depth to groundwater and/or soil type on the leaching of waste constituents from retention ponds or corrals. Four generalized environments were simulated: two representing shallow groundwater (5 ft or 10 ft) and two representing a deep unsaturated zone (150 ft). For each water table configuration, two soil profiles were modeled: one consisting of a permeable sand (1×10^{-3} cm/sec) and one consisting of a relatively low-permeability clay (1×10^{-6} cm/sec). Dilution in groundwater was calculated assuming an approximately 10-foot-thick sand aquifer. The physical parameters for each of the assumed environments are summarized in Table A-1.

In addition to these parameters, each model required input data regarding the vadose zone, the assumed aquifer, and contaminant types, concentrations, and loading rates. These data are summarized in Tables A-2, A-3a, and A-3b. It is important to understand that these assumed environments and parameters do not model any known or actual site conditions in the Central Valley of California. Rather, they are intended to demonstrate the relative effects that subsurface geologic conditions and different loading assumptions may have on the migration of waste constituents from corrals or retention ponds.

Waste Constituents and Concentrations

The composition of manure at a particular confined animal facility depends on a number of factors such as the animal species, size, maturity, health, and the composition of animal feed. As summarized above, the principal pollutants associated with animal wastes with the potential to affect groundwater quality include nitrogen and salts (BVA 2003). As a result, the comparative modeling assessment considered the fate and transport of these

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[1] SESOIL is an acronym for Seasonal Soil compartment model, a one-dimensional vertical transport model for the unsaturated soil zone that is an integrated screening-level analytical model designed to simultaneously calculate water transport, sediment transport, and contaminant fate. AT123D is a generalized three-dimensional groundwater model used to estimate concentrations of contaminants transported, dispersed, degraded and adsorbed in one-, two-, or three-dimensional groundwater flow.

compounds in the subsurface below corrals and retention ponds. Fundamental assumptions used to select constituents for modeling included:

- Principal nitrogen compounds associated with animal waste include ammonium, organic nitrogen, and nitrate. As indicated above, ammonium and organic nitrogen are frequently fixed to soil particles and relatively immobile in the subsurface. However, in the presence of oxygen, ammonium can convert to nitrate, which is mobile and toxic. Therefore, the modeling performed for this study was based on nitrate as the representative form of nitrogen because it is typically considered to be a "conservative" (i.e. non-reactive, non-retarded) constituent in the subsurface.

- Total salt concentrations are typically presented as total dissolved solids (TDS). From a modeling standpoint, however, TDS is not a functional variable because it has no established chemical characteristics and the fate and transport of high TDS solutions will depend on the specific mixture of ionic species that are present and the nature of the subsurface soils (particularly the cation exchange capacity). Therefore, rather than attempt to simulate the movement of a complex and poorly defined mixture of ionic compounds, the modeling completed for this study focused on chloride as a surrogate compound because it is a conservative compound that does not significantly degrade or attenuate in the subsurface (positively charged salt ions such as sodium, calcium, magnesium, and potassium, on the other hand, may be strongly adsorbed and attenuated in clayey subsurface environments).

Input loading concentrations for retention ponds and corrals are difficult to predict because of site-specific biochemical transformations in the subsurface. Accordingly, for the purposes of this study, seepage and leaching analyses were based on constant unit concentrations (mg/L for retention pond seepage and kg/acre/mo for corral leaching). Because the analyses are linear functions, the ratio of leakage or loading rates to concentration in groundwater will remain constant if all other factors are held equal. This allows use of the model to draw conclusions regarding groundwater impacts as a function of seepage rate (described below), subsurface materials (sand and clay), and depth to groundwater (5 ft or 10 ft, and 150 feet).

Seepage and Infiltration Rates

Leakage rates were varied over a range to model seepage from clay-lined and synthetic-lined basins. For the purposes of these analyses, seepage from clay-lined retention ponds was assumed to be consistent with the values recommended for Alternative 3 and consistent with NRCS guidance (1×10^{-6} cm/sec with no credit given for manure sealing). Based on data included in Bonaparte et al. (2002), leakage from synthetic-lined retention ponds was assumed to range from a low value of about 0.2 gallons per acre per day (gpad) to a high value of about 21 gpad to account for good to poor construction quality, respectively.

Infiltration rates below a corral will depend largely on precipitation and conditions at the surface of the corral. For the purposes of this evaluation, the corral was assumed to be underlain by either: (i) natural geologic materials with the properties described above and summarized in Table A-1; or (ii) an upper one foot compacted clay layer with an assumed hydraulic conductivity of 3 x 10^{-7} cm/sec.[2] The second scenario also assumed a one foot thick layer of protective soil with a permeability of 5 x 10^{-6} cm/sec was present on top of the compacted barrier layer.

Climatologic Values

SEVIEW includes climate data for several thousand locations, including the Central Valley cities of Madera, Fresno, and Bakersfield. For the purpose of this evaluation, all modeling was performed using the Madera data. The SEVIEW data set only includes one year of climate data, corresponding to a "normal" year, and repeats this input for each simulated year. Although SEVIEW limits the exposure period to 99 years for the purposes of calculating contaminant concentrations in groundwater, it calculates an estimated "breakthrough time for contaminants to reach the groundwater.

Results

General

The MULTIMED modeling results are summarized in Table A-4 and indicate under steady-state assumptions, retention pond leakage may cause increases in the concentrations of nitrate and chloride in groundwater under any of the geologic conditions that were assumed for analysis. For example, the predicted dilution attenuation factor (DAF) under a number of different scenarios ranges from 1 (essentially no dilution) for clay-lined basins, to a relatively high value of 754 for high quality synthetic-lined basins that are underlain by clay soils. Although these results indicate that leakage rates, subsurface soil types, and the thickness of the unsaturated zone under retention ponds all influence the potential for groundwater impacts, the leakage rate from a retention pond is a dominant factor. It should be noted that as used herein, the results in Table A-4 provide no information regarding whether groundwater will be affected above some specified limit. Rather, the results indicate that some impact, whether detectable or not, and whether above some specified limit or not, is likely to occur at some time in the future. As shown by the SEVIEW results, however, the time can very long (several hundred years) in environments where groundwater occurs at depth and/or the facility is underlain by low permeability materials.

Potential chloride leaching rates from the corral scenarios are summarized in Table A-5 and indicate that the geologic setting largely determines the vulnerability of groundwater. In particular the SEVIEW results show that the time required for the modeled constituents to reach the groundwater can range from a few months to more than 450 years, depending

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[2] The SEVIEW model does not allow very low permeability layers at the ground surface. The 3 x 10^{-7} cm/sec value represents the lowest practicable model value.

largely on soil type and depth to groundwater. For example, the model calculates breakthrough times as short as 0.08 years for a facility that is underlain by sand with the groundwater table 10 feet below the ground surface or 8.1 years for the same facility with the groundwater occurring at a depth of 150 feet below the ground surface. By comparison, the assumption of clay subsurface conditions increases the breakthrough time to 31 years and more than 450 years depending on the infiltration rate and the depth to groundwater.

It also should be noted that the concentrations in groundwater beneath corrals were based on an assumed aquifer that was only 10 feet thick. A thicker saturated zone would result in greater dilution, higher attenuation factors, and relatively lower contaminant concentrations in groundwater. It is also noted that the corral analyses did not account for a surface seal that may form and limit infiltration from corral areas. Therefore, if such a seal is present, the corral analyses may overestimate chloride concentrations in groundwater and underestimate the breakthrough time to groundwater.

Implications

The model results described above and summarized in Table A-4 indicate that the risk of groundwater contamination at any facility is not only dependent on the seepage rate from waste retention ponds or the leaching rate from corral areas, but also depends on the chemical characterizations in the waste, the depth to the water table, and the subsurface soil properties that influence waste transformation and migration in the subsurface. Ham and DeSutter (2000) argue that site-to-site variation in these properties is so great that retention pond design should be site specific and also state that "no science-based framework exists for collecting site-specific input data and calculating the appropriate design criteria for each individual lagoon." However, the data and modeling support several broad and largely intuitive conclusions important to the development of minimum criteria intended to protect groundwater quality:

- Limiting retention pond seepage or infiltration from corral areas is a dominant factor which reduces the potential for, and degree of, future groundwater impacts;

- The presence of clay minerals in the liner system and/or the underlying geologic materials reduces the potential for future groundwater impacts because of their adsorptive capacity for ammonium, organic nitrogen, and cation salts. However, modeling results and data indicate that anions or non-reactive contaminants such as nitrate may ultimately affect groundwater;

- A large unsaturated zone between a retention pond and the water table is an advantage because some compounds adsorb to the clay particles and mobile ions such as nitrate and chloride move slowly in unsaturated soil as the hydraulic conductivity of this zone decreases with declining water content.

Appendix A

<table>
<tr><td colspan="7" align="center">Table A-1
SUMMARY OF ASSUMED GEOLOGIC INPUT PARAMETERS</td></tr>
<tr><td align="center">PARAMETER</td><td align="center">UNITS</td><td colspan="4" align="center">UNSATURATED (VADOSE) ZONE</td><td align="center">AQUIFER</td></tr>
<tr><td>Layer Thickness</td><td>feet</td><td>5 and 10 ft</td><td>5 and 10 ft</td><td>150 ft</td><td>150 ft</td><td>10 ft</td></tr>
<tr><td>Principal soil type</td><td>N/A</td><td>Sand</td><td>Clay</td><td>Sand</td><td>Clay</td><td>Sand</td></tr>
<tr><td>Bulk density</td><td>g/cm^3</td><td>1.58</td><td>1.68</td><td>1.58</td><td>1.68</td><td>1.58</td></tr>
<tr><td>Hydraulic conductivity</td><td>cm/sec</td><td>1×10^{-3}</td><td>1×10^{-6}</td><td>1×10^{-3}</td><td>1×10^{-6}</td><td>1×10^{-3}</td></tr>
<tr><td>Effective porosity</td><td>no units</td><td>0.25</td><td>0.25</td><td>0.25</td><td>0.25</td><td>0.25</td></tr>
<tr><td>Soil pore disconnectedness coefficient</td><td>no units</td><td>4</td><td>12</td><td>4</td><td>12</td><td>NA</td></tr>
<tr><td>Organic carbon content</td><td>mg/L</td><td>0.1</td><td>0.7</td><td>0.1</td><td>0.7</td><td>0.01</td></tr>
<tr><td>Cation exchange capacity</td><td>meq/100 gm</td><td>0</td><td>10</td><td>0</td><td>10</td><td>NA</td></tr>
<tr><td>pH</td><td>units</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td></tr>
<tr><td colspan="7">NOTES:
1. All material properties assumed.
2. Minimum depth to groundwater assumed to be 5 ft for MULTIMED modeling and 10 feet for SEVIEW modeling (the transient SEVIEW model does not allow the relatively shallower depth for groundwater).
3. Effective porosity is not a significant variable for the steady state MULTIMED value. The "soil pore disconnectedness coefficient" is used in SEVIEW for vadose zone velocity calculations</td></tr>
</table>

<table>
<tr><td colspan="7" align="center">Table A-2
SUMMARY OF MULTIMED INPUT PARAMETERS</td></tr>
<tr><td align="center">Parameter</td><td align="center">Shallow Sand</td><td align="center">Deep Sand</td><td align="center">Shallow Clay</td><td align="center">Deep Clay</td><td align="center">Units</td><td align="center">Comments</td></tr>
<tr><td colspan="7" align="center"><i>Contaminant Source Parameters</i></td></tr>
<tr><td>Retention pond leakage rate</td><td>1×10^{-6} to 2.2 $\times 10^{-10}$</td><td>1×10^{-6} to 2.2 $\times 10^{-10}$</td><td>1×10^{-6} to 2.2 $\times 10^{-10}$</td><td>1×10^{-6} to 2.2 $\times 10^{-10}$</td><td>cm/sec</td><td>Leakage rate varied to account for soil liner, poor quality synthetic liner, & good quality synthetic liner. See text and Table A-4.</td></tr>
<tr><td>Area of retention pond</td><td>4,000</td><td>4,000</td><td>4,000</td><td>4,000</td><td>m^2</td><td>Assumed one acre</td></tr>
<tr><td>Recharge rate</td><td>3.17×10^{-7}</td><td>3.17×10^{-7}</td><td>3.17×10^{-7}</td><td>3.17×10^{-7}</td><td>cm/sec</td><td>Assumed value</td></tr>
<tr><td>Source decay constant</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1/yr</td><td>Assumption that assumes constant input loading</td></tr>
<tr><td>Duration of leakage</td><td>Constant</td><td>Constant</td><td>Constant</td><td>Constant</td><td>yr</td><td>Assumed</td></tr>
<tr><td>Spread of contaminant source</td><td>Model Predicted</td><td>Model Predicted</td><td>Model Predicted</td><td>Model Predicted</td><td>m</td><td>Derived by model</td></tr>
<tr><td>Length scale of facility</td><td>Model Predicted</td><td>Model Predicted</td><td>Model Predicted</td><td>Model Predicted</td><td>m</td><td>Derived by model</td></tr>
</table>

Table A-2 **SUMMARY OF MULTIMED INPUT PARAMETERS**						
Unsaturated Zone Flow and Transport Parameters						
Number of layers	1	1	1	1	1	Conservative assumption
Thickness	5	150	5	150	ft	Assumed for analysis
Saturated hydraulic conductivity (vertical)	1.0E-03	3.1E-03	1.0E-06	1.0E-06	cm/sec	Assumed values
Effective Porosity	0.25	0.25	0.25	0.25	none	Assumed values, typical value for soils
Air entry pressure head	0	0	-0.003	-0.003	m	Assumed values, typical for sand (0) and clay (-)
Residual water Content	0.045	0.045	0.068	0.068	none	Assumed based on model guidance
Van Genuchten coefficients	Alpha 0.145, Beta 2.68	Alpha 0.145, Beta 2.68	Alpha 0.08, Beta 1.09	Alpha 0.08, Beta 1.09	none	Assumed based on model guidance
Organic matter	0.1	0.1	0.4	0.4	%	Assumed values for shallow soils
Bulk density	1.6	1.6	1.7	1.7	g/cm^3	Model guidance for silty sand and clay
Biological decay coefficient	0	0	0	0	none	Assumes no decay for Chloride, NO_3^- (conservative constituents)
Groundwater Transport Parameters						
Aquifer thickness	10	10	10	10	ft	Assumed value
Effective Porosity	0.25	0.25	0.25	0.25		Typical value for effective porosity
Bulk density	1.6	1.6	1.6	1.6	g/cm^3	Typical value for silty sand
Mixing zone depth	Model Predicted	Model Predicted	Model Predicted	Model Predicted	m	Derived by model
Mean particle diameter	0.01	0.01	0.01	0.01	cm	Model guidance for fine sand
Hydraulic conductivity	9.99 x 10^{-4}	9.99 x 10^{-4}	9.99 x 10^{-4}	9.99 x 10^{-4}	cm/sec	Assumed value for sand
Gradient	0.003	0.003	0.003	0.003	none	Assumed value
Seepage velocity	Model Predicted	Model Predicted	Model Predicted	Model Predicted	m/yr	Calculated by model
Retardation coefficient	Model Predicted	Model Predicted	Model Predicted	Model Predicted	none	Derived by model
Dispersivity	Model Predicted	Model Predicted	Model Predicted	Model Predicted	m	Derived by model
Temperature	19	19	19	19	deg. C	Assumed value
pH	7	7	7	7	units	Assumed value
Organic carbon content	0.0001	0.0001	0.0001	0.0001		Assumed value
Distance to well (or distance from impoundment where concentration is calculated)	10	10	10	10	ft	Assumed value

Appendix A

		SUBSURFACE CONDITIONS		
PARAMETER	UNITS	Sand	Clay	COMMENT/BASIS
Table A-3a **SUMMARY OF SEVIEW VADOSE ZONE AND AQUIFER INPUT PARAMETERS**				
Soil Parameters				
Hydraulic Conductivity	cm/sec	1×10^{-3}	1×10^{-6}	Assumed typical values for sand and clay
Bulk Density	g/cm^3	1.6	1.7	Typical values for sand and clay based on SEVIEW model guidance
Intrinsic Permeability	cm^2	1×10^{-8}	3×10^{-11}	Derived from Hydraulic Conductivity values
Soil Pore Disconnectedness Index	none	4	12	Range of values from SEVIEW model guidance
Effective Porosity	none	0.25	0.25	Assumed typical values, consistent with model guidance (model used soil pore disconnectedness index for velocity calculations)
Organic Carbon Content	%	0.1	0.7	Assumed values for shallow soils
Cation Exchange Capacity	meq/100gm	0	10	Assumed values, based on model guidance for sand & clays
Freundlich Exponent	none	1	1	Assumed value (not used for conservative, non-reacting compounds)
Depth to Water Table	ft	10 and 150	10 and 150	Assumed values to bracket shallow and deep conditions
Precipitation Data	none	Madera	Madera	Assumed generally representative of Central Valley
Aquifer Transport Parameters				
Hydraulic Conductivity	m/hr	3.6×10^{-2}	1.8×10^{-4}	Assumed values for sand and clay
Gradient	none	0.003	0.003	Assumed typical value for alluvial aquifer
Effective porosity	none	0.25	0.25	Assumed typical values for soil
Soil Bulk Density	kg/m^3	1.6×10^3	1.7×10^3	Typical values for sand and clay based on SEVIEW model guidance
Longitudinal Dispersivity	m	2.16	2.16	Scale-dependent, assumed value based on model guidance
Lateral Dispersivity	m	0.2	0.2	Scale-dependent, assumed value based on model guidance
Vertical Dispersivity	m	0.02	0.02	Scale-dependent, assumed value based on model guidance
Aquifer Width	m	infinite	infinite	No boundary conditions assumed
Aquifer Thickness	m	3	3	Assumed value. Thicker aquifer will result in higher dilution
Organic Carbon Content	%	0.1	0.7	Assumed values for shallow soils

Table A-3a SUMMARY OF SEVIEW VADOSE ZONE AND AQUIFER INPUT PARAMETERS				
PARAMETER	UNITS	SUBSURFACE CONDITIONS		COMMENT/BASIS
		Sand	Clay	
Organic Carbon Adsorption Coefficient	(ug/g)/(ug/ml)	0	0	Not used for conservative (non-adsorbing) constituents
Distribution Coefficient	m^3/kg	0	0	Not used for conservative constituents
Water Diffusion Coefficient x Tortuosity	m^2/hr	3.53×10^{-6}	3.53×10^{-6}	Assumed value from model guidance

Appendix A

<table>
<tr><th colspan="5">Table A-3b
SUMMARY OF SEVIEW CHEMICAL AND CONTAMINANT LOADING INPUT PARAMETERS</th></tr>
<tr><td rowspan="2">PARAMETER</td><td rowspan="2">UNITS</td><td colspan="2">CHEMICAL CONSTITUENTS</td><td rowspan="2">COMMENT/BASIS</td></tr>
<tr><td>Nitrate</td><td>Chloride</td></tr>
<tr><td colspan="5" align="center"><i>Contaminant Load Parameters</i></td></tr>
<tr><td>Area</td><td>cm^2</td><td>4 x 10^7</td><td>4 x 10^7</td><td>Assumed value (approximately one acre)</td></tr>
<tr><td>Latitude</td><td>degrees</td><td>36.95</td><td>36.95</td><td>Madera, CA</td></tr>
<tr><td>Type of Load</td><td>none</td><td>continuous</td><td>continuous</td><td>Assumes a net addition of manure constituents to soils each month (less than 100% removal efficiency)</td></tr>
<tr><td>Load Rate</td><td>kg/acre/mo</td><td>1</td><td>1</td><td>See text. Load rate is the net addition, i.e. amount remaining after scraping etc. Contaminant load assumed to be mixed into the top one foot of soil.</td></tr>
<tr><td>Mass of Contaminant Transformed</td><td>ug/cm^2/mo</td><td>0</td><td>0</td><td>Assumes contaminant does not transform into other compounds. Conservative assumption.</td></tr>
<tr><td>Mass of Contaminant Removed</td><td>ug/cm^2/mo</td><td>0</td><td>0</td><td>Conservative assumption. Contaminant removal is accounted for in the load rate calculations.</td></tr>
<tr><td>Ligand Load</td><td>ug/cm^2/mo</td><td>0</td><td>0</td><td>Not applicable to conservative (non-reactive) constituents.</td></tr>
<tr><td>Volatilization/Diffusion Index</td><td>none</td><td>0</td><td>0</td><td>Not applicable to non-volatile constituents.</td></tr>
<tr><td>Runoff/Infiltration Transport Index</td><td>none</td><td>0.4</td><td>0.4</td><td>Ratio of mass of contaminant in runoff to mass in water infiltrating soil. Assumed value for soluble constituents.</td></tr>
<tr><td>Solubility Index</td><td>none</td><td>0</td><td>0</td><td>Not used for conservative constituents.</td></tr>
<tr><td>Sublayer Load Parameters</td><td>various</td><td>0</td><td>0</td><td>Not used. All loads applied to uppermost soil layer.</td></tr>
<tr><td colspan="5" align="center"><i>Chemical Parameters</i></td></tr>
<tr><td>Solubility</td><td>mg/L</td><td>6 x 10^5</td><td>3.7 x 10^5</td><td>From chemical data.</td></tr>
<tr><td>Air Diffusion Coefficient</td><td>cm^2/sec</td><td>0</td><td>0</td><td>Not used (non-volatile constituents).</td></tr>
<tr><td>Henry's Law Constant</td><td>m^3-atm/mol</td><td>0</td><td>0</td><td>Not used for non-volatile constituents.</td></tr>
<tr><td>Organic Carbon Adsorption Coefficient</td><td>(ug/L)/(ug/L)</td><td>0</td><td>0</td><td>Not used for conservative (non-adsorptive) constituents.</td></tr>
<tr><td>Distribution Coefficient</td><td>(ug/L)/(ug/L)</td><td>0</td><td>0</td><td>Not used for conservative (non-adsorptive) constituents.</td></tr>
<tr><td>Molecular Weight</td><td>g/mole</td><td>62</td><td>35.5</td><td>From chemical data.</td></tr>
<tr><td>Valence</td><td>g/mole</td><td>0</td><td>0</td><td>Parameter not used for non-reactive constituents.</td></tr>
<tr><td>Neutral Hydrolysis Rate Constant</td><td>L/mole/day</td><td>0</td><td>0</td><td>Not used for conservative constituents that do not spontaneously dissociate.</td></tr>
</table>

		CHEMICAL CONSTITUENTS		
Table A-3b **SUMMARY OF SEVIEW CHEMICAL AND CONTAMINANT LOADING INPUT PARAMETERS**				
PARAMETER	UNITS	Nitrate	Chloride	COMMENT/BASIS
Base Hydrolysis Rate Constant	L/mole/day	0	0	Not used for conservative constituents that do not spontaneously dissociate.
Acid Hydrolysis Rate Constant	L/mole/day	0	0	Not used for conservative constituents that do not spontaneously dissociate.
Liquid Phase Biodegradation Rate	L/day	0	0	Assumes no biodegradation of nitrate and chloride
Solid Phase Biodegradation Rate	L/day	0	0	Assumes no biodegradation of nitrate and chloride
Ligand Stability Constant	none	0	0	Not used for constituents that do not react with ligands (form chemical complexes). Conservative assumption for nitrate.
Moles Ligand/Moles Compound	none	0	0	Not used; see above.
Water Diffusion Coefficient	cm^2/sec	0	9.8×10^{-6}	From SEVIEW model guidance. Only used in groundwater flow model (AT123D).
Molecular Weight of Ligand	g/mole	0	0	Not used; see above.

TABLE A-4 SUMMARY OF MULTIMED ANALYSIS RESULTS					
GEOLOGIC ENVIRONMENT	**ASSUMED LINER SYSTEM**	**ASSUMED LEAKAGE RATE (cm/sec)**	**ASSUMED INITIAL CONCENTRATION (mg/L)**	**CALCULATED CONCENTRATION IN GROUNDWATER (mg/L)**	**DILUTION ATTENUATION FACTOR (DAF)**
Vulnerable Conditions (Shallow Groundwater)					
Shallow sand	Compacted clay	1×10^{-6}	1	0.95	1
Shallow sand	Synthetic (poor construction)	2.2×10^{-8}	1	0.32	3
Shallow sand	Synthetic (good construction)	2.2×10^{-10}	1	0.00343	292
Shallow clay	Compacted clay	1×10^{-6}	1	0.95	1
Shallow clay	Synthetic (poor construction)	2.2×10^{-8}	1	0.13	7.5
Shallow clay	Synthetic (good construction)	2.2×10^{-10}	1	0.0013	754
Less Vulnerable Conditions (Deep Groundwater)					
Deep sand	Compacted clay	1×10^{-6}	1	0.95	1
Deep sand	Synthetic (poor construction)	2.2×10^{-8}	1	0.32	3
Deep sand	Synthetic (good construction)	2.2×10^{-10}	1	0.0032	313
Deep clay	Compacted clay	1×10^{-6}	1	0.95	1
Deep clay	Synthetic (poor construction)	2.2×10^{-8}	1	0.13	7.5
Deep clay	Synthetic (good construction)	2.2×10^{-10}	1	0.0013	754

NOTES:
1. Analyses are steady-state. Therefore, the amount of time required to affect groundwater is not known and could be significant for deep groundwater.
2. Conservative constituents were assumed (chloride and nitrate). Therefore, no significant attenuation was calculated in the vadose zone and no difference in concentrations between the constituents was calculated.
3. Leakage rates for synthetic liner systems based on studies by Bonaparte et al. (2002).
4. Shallow geologic environment assumes groundwater occurs 5 feet below the ground surface.
5. Deep geologic environment assumed groundwater occurs 150 feet below the ground surface.
6. See Tables A-1 and A-2 for model input parameters. Homogeneous conditions assumed.

TABLE A-5
SUMMARY OF SEVIEW MODELING RESULTS FOR CORRALS

ASSUMED DEPTH TO GROUNDWATER (feet)	ASSUMED SOIL TYPE (HYDRAULIC CONDUCTIVITY)	ASSUMED CHLORIDE LOADING RATE (kg/acre/month)	CALCULATED CHLORIDE CONCENTRATION IN GROUNDWATER (mg/L)	LEACHING COEFFICIENT (mg/L/(kg/acre/month))	CALCULATED BREAKTHROUGH TIME (years)
		Chloride	Chloride	Chloride	
10 ft	Sand (1 x 10^{-3} cm/sec)	1	18	18	0.08
10 ft	Clay (1 x 10^{-6} cm/sec)	1	28	28	31
10 ft	1 ft Protective soil layer (5 x 10^{-6} cm/sec) 1 ft Barrier layer (3 x 10^{-7} cm/sec) underlain by clay (1 x 10^{-6} cm/sec)	1	15	15	75
150 ft	Sand (1 x 10^{-3} cm/sec)	1	20	20	8.1
150 ft	Clay (1 x 10^{-6} cm/sec)	1	NC	NC	356
150 ft	1 ft Protective soil layer (5 x 10^{-6} cm/sec) 1 ft Barrier layer (3 x 10^{-7} cm/sec) underlain by clay (1 x 10^{-6} cm/sec)	1	NC	NC	480

NOTES:
1. Analyses are transient and based on "normal year" climatologic data for Madera, California.
2. Conservative constituents were assumed (chloride). Therefore, no significant attenuation was calculated in the vadose zone or groundwater.
3. See Tables A-1, A-3a, A-3b for model input parameters.
4. The calculated concentration in groundwater represents an annual average concentration at the end of the simulation period. The modeled concentrations vary on a seasonal basis in response to precipitation.
5. The unit chloride loading rates used for this evaluation were assumed. However, the analyses are linear and the "leaching coefficient" calculated by this procedure can be used to calculate a groundwater concentration for any other assumed loading rate (all other factors remaining equal).
6. NC - SEVIEW does not calculate a concentration in groundwater for exposure periods longer than 99 years.
7. Calculated groundwater concentrations based on a 10 foot thick aquifer. Lower concentrations would result for a thicker aquifer. The increased concentrations in clay relative to sand aquifers result from the greater amount of dilution that would be expected in a sand aquifer.

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